My Evolutionary Trajectory:

notes towards an intellectual autobiography

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Abstract: The following essay is an attempt to make a global assessment of the things I have achieved up to now during my academic career. It is an occasion for me to summarize and review an intellectual trajectory that is very wide-ranging and multidisciplinary, and that therefore may seem to lack focus. Yet, that trajectory has actually been driven by an enduring fascination for self-organization, and the desire to build a coherent and comprehensive conceptual framework for modeling this phenomenon. To clarify this drive and the intellectual evolution it produced, I will start with my family background and childhood, move on to my university study and PhD in physics, review the communities in which I have been closely involved, including Principia Cybernetica, the Global Brain Group, and the Evolution, Complexity and Cognition group, and finally summarize my most recent ideas that synthesize this variety of experiences and perspectives.

Family background

I was born on September 27, 1960, in the small Flemish town of Vilvoorde just outside Brussels, the capital of Belgium. My father, Constant, was educated as a civil engineer specialized in aeronautics. He had always been fascinated by aviation, but his work consisted mostly of supervising more prosaic industrial operations, such as the local cokes factory. This seemed to be rather frustrating to him, given his initially high ambitions. The fact that he twice lost his job after a downsizing or factory closure only added to his stress. My mother, Suzy, an intelligent and open-minded woman, had started to study Germanic languages but never finished her studies. She stayed at home, looking after me and my two younger brothers, Philip and René, while deftly managing the household, even during the lean times when my father was unemployed. Both had studied at the *Université Libre de Bruxelles*, the then exclusively French-speaking *Free University of Brussels*.

My two grandfathers, Ernest (paternal) and Frans (maternal), were both primary school teachers who ended their careers as school directors, retiring shortly after I was born. Both were also locally known authors. Ernest wrote serial adventure stories for adolescents, earning quite some money from the proceeds. Frans wrote a variety of humoristic plays, poetry, and autobiographical stories that did not sell much, but that were much appreciated in the family circle. Frans had the more romantic, artistic temperament, and was active with drawing, painting and music (as a choir director), while moreover practicing photography in an era when you still had to develop your own pictures in a dark room. Ernest had a more rationalistic, scientific temperament, but his hobbies were limited to stamp collecting. They both had more influence on my education than my father, who, while well intended, always seemed too busy or too tired to have much time for his children. The most important lesson I learned from him was that I definitely did not want to follow in his footsteps. This may explain my initial disdain for business, engineering and other applied domains.

Constant and Suzy showing off their firstborn, Francis

The general family spirit was one of intellectual curiosity, stimulating me to explore and learn about a variety of artistic, literary and scientific subjects, but never imposing anything specific. While my parents would have liked me to study medicine or engineering, they never seriously objected when I came up with less practical career plans. The basic family values were freethinking; a progressive, liberal mind-set; respect for the classics in science, culture and music; and a healthy sense of ambition and self-confidence. My brothers and I were stimulated to be the best in our class (something that Philip and I certainly were capable of), but did not really get criticized if we merely came second or third (my brother René, on the other hand, was not doing so well at school).

After kindergarten I went to the neighborhood primary school in Vilvoorde, and then in 1972 to a secondary school in Mechelen, the *Koninklijk Atheneum Pitzemburg*, whose director was an acquaintance of my father. Given my parents' (and my own) intellectual ambition, I took the most difficult option, combining Latin with advanced mathematics. For my subsequent university studies, it had always been evident that I would go to the Free University of Brussels, both because its freethinking philosophy matched the one of my family, and because it was near to where we lived. While apparently I did not have much choice in the matter, I have never regretted studying there, because the "freedom" in its name effectively implied a very open, informal and forward-thinking culture among its students and faculty. This intellectual freedom is what later allowed me to pursue a broad variety of non-traditional subjects in my research.

Childhood interests

Since my childhood, I have been interested by all forms of complexity and self-organization. I was always a keen observer of nature, being fascinated by complex phenomena such as ants walking apparently randomly across a branch, the cracks that would appear in drying mud, or the frost crystals that would form on grass during winter nights.

As an adolescent, one of my hobbies was keeping aquariums, in which I would try to build a miniature ecosystem complete with soil, plants, invertebrates, and fish. The fish would still need to get food from time to time, and I still had to clean the filter that would collect the dirt they produced, but ideally I would have liked to create a system that is completely autonomous, and is able to sustain itself even in the absence of a caretaker. That would have required more plant life to sustain the food chain, and especially less fish to produce waste products, so it would have made the aquarium less interesting to look at. Therefore, I did compromise in practice. But in my imagination, I was fascinated by what I called "a little world on its own". In my present scientific vocabulary, I would define this idea as a system that is complex and self-organizing to such a degree that it could be viewed almost as a separate, autonomous universe. (Later I discovered a similar idea in the science fiction stories of Stanislaw Lem, a Polish author influenced by cybernetics.)

My fascination for rocks, plants, animals and other phenomena of nature also found an outlet in my early inquiry into the theory of evolution. Like most children nowadays, I had been exposed from an early age to pictures and stories about dinosaurs. The difference, perhaps, is that my grandfather Ernest who had collected or drawn these pictures for me was rather scientifically minded. He taught me not only their Latin names, such as Brontosaurus, Triceratops and Tyrannosaurus Rex, but also about the periods in which they lived, and the kinds of creatures that preceded and followed them in the course of natural history. So, from an age of eight or so, I was well aware that life on Earth had evolved, and that plants and animals looked very different in different time periods.

Two Foundational Principles

As I became a little older, I started reading introductory books on biology, which explained the mechanism of natural selection behind this evolution. This idea became one of the two fundamental principles on which I have based my scientific worldview. As an adolescent, this mechanism seemed so obvious to me that I was quick to generalize it to other domains, noting that for example ideas and societies also evolved through variation and selection. I called this "the generalized principle of natural selection".

Much later, while working on my PhD, I came into contact with other scientists (in particular the great Donald T. Campbell[1] and his disciples Gary Cziko[2] and Mark Bickhard[3]) who had developed a similar philosophy, which they called "selectionism" or "universal selection theory", and which Richard Dawkins later called "universal Darwinism"[4]. Its basic assumption is that all complex systems—whether physical, biological, mental or social—have originated through an evolutionary process, which at the deepest level consists of some form of "blind" (not necessarily random) variation, followed by the selective retention of those variants that are most "fit" [5].

In this radical formulation, the theory has few adherents. The reason is that most complexity scientists view Darwin's theory of natural selection with its emphasis on individual organisms or genes as reductionist, ignoring the "whole is greater than the sum of the parts" mantra that characterizes self-organization and complex systems. Yet, I never saw a contradiction between this holistic perspective and my beloved principle of natural selection. The explanation lies in another fundamental idea that I developed while I was 15-16 years old, and which I called the "relational principle".

After reading popular science accounts of Einstein's theory of relativity, I was inclined to conclude, like so many others with a somewhat rebellious streak, that "everything is relative", and that there are no absolute laws nor truths, neither man-made nor natural. (Later I learned that Einstein's own philosophy could hardly have been more different). More recently, this irreverent philosophy has gotten some form of academic respectability under the label of "postmodernism" or "social constructivism". Its main thesis is that different cultures and different people see the same things in different ways, and that there is no absolute criterion to say who is right and who is wrong. But this negative interpretation did not satisfy me: I wanted to truly understand how the world functions.

Therefore, I focused on the positive aspect of relativity: the importance of relations. A phenomenon can only be conceived with respect to, or *in relation to*, another phenomenon. No phenomenon can exist on its own—without context or environment from which it is distinguished, but to which it is at the same time connected. Later, this idea led me to analyze everything in terms of "bootstrapping" networks[6], where nodes are defined by their links with other nodes, and links by the nodes they connect. This philosophy is intrinsically holistic: it is impossible to reduce systems to their separate components; it is only through the connections between the components that the system emerges. This relational point of view is not in conflict with selectionism: networks do undergo variation and selection, both at the level of the nodes and links that constitute them and at the higher level of the systems that emerge from clusters of densely linked nodes.

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[1] D. T Campbell, "Blind Variation and Selective Retention in Creative Thought as in Other Knowledge Processes," *Psychological Review* 67, no. 6 (1960): 380–400; M. H Bickhard and D. T Campbell, "Variations in Variation and Selection: The Ubiquity of the Variation-and-selective-retention Ratchet in Emergent Organizational Complexity," *Foundations of Science* 8, no. 3 (2003): 215–282; D. T Campbell, "Evolutionary Epistemology," *Evolutionary Epistemology, Rationality, and the Sociology of Knowledge* (1987): 47–89.

[2] G. Cziko, *Without Miracles: Universal Selection Theory and the Second Darwinian Revolution* (The MIT Press, 1997).

[3] Bickhard and Campbell, "Variations in Variation and Selection."

[4] J. W. Stoelhorst, "Universal Darwinism from the Bottom up: An Evolutionary View of Socio-economic Behavior and Organization," *Wolfram Elsner and Hardy Hanappi, Advances in Evolutionary Institutional Economics: Evolutionary Modules, Non-Knowledge, and Strategy. Cheltenham: Edward Elgar Publishers* (n.d.); G. M Hodgson and T. Knudsen, "Why We Need a Generalized Darwinism, and Why Generalized Darwinism Is Not Enough," *Journal of Economic Behavior & Organization* 61, no. 1 (2006): 1–19.

[5] Francis Heylighen, "Principles of Systems and Cybernetics: An Evolutionary Perspective," *Cybernetics and Systems' 92* (1992): 3–10.

[6] Francis Heylighen, "Bootstrapping Knowledge Representations: From Entailment Meshes via Semantic Nets to Learning Webs," *Kybernetes* 30, no. 5/6 (2001): 691–725, http://pespmc1.vub.ac.be/papers/BootstrappingPask.pdf.

Studying Physics

After having formulated the fundamental tenets of my philosophy already while in high school, my challenge was to choose a discipline to study in university. With such a broad interest in complex systems of all types (I had even "reinvented" the concept of social network by drawing a map of all the relationships within my high school class—an exercise that did not make me too popular among my classmates), coupled with a healthy skepticism towards traditional reductionist science, this was not an obvious issue. I hesitated between biology, physics, philosophy and literature, and finally settled on physics, reasoning that I could study the other ones on my own, but with the math underlying physics being so difficult, I would need some solid tutoring if I wanted to become mathematically literate enough to understand the most advanced theories. This reasoning turned out to be correct: studying theoretical physics was hard, but it gave me a basis that allowed me to afterwards investigate a variety of other scientific disciplines on my own.

Within physics, my interest initially did not go towards complexity—which at the time (around 1980) was not yet a fashionable topic. I was lucky enough to get some courses on thermodynamics and statistical mechanics from professors who had worked with the great Ilya Prigogine[7], the founder of the Brussels School of complex systems. But these particular individuals were less inspiring to me than a young assistant researcher, Diederik Aerts, who was investigating the foundations of quantum mechanics[8]. So, I decided to make, first my Master's thesis, then my PhD on that subject, hoping to be able to elaborate my relational philosophy in a more formal manner.

I started my PhD research in theoretical physics (1982), mainly because at the time physics seemed to be the science that offered the best hope for me to understand the architecture of the universe. My brief foray in the foundations of its most important, non-classical theories[9] (quantum mechanics, relativity theory and thermodynamics) provided me with the rudiments of a fundamentally new framework for the representation of change. The main result of my PhD thesis[10] was the concept of distinction dynamics. This denotes the idea that the distinctions (between objects, properties, or states) made in scientific theories are not invariant, as classical, Newtonian science tends to assume, but subject to processes of creation and destruction. In addition, I showed how in principle the structure of space-time could be generated from a "bootstrapping" formalism[11] that is purely dynamic and relational, without assuming static elements or objects. While foundational, these results remained very abstract and general. In a sense, my later work in cognitive science, cybernetics and systems can be seen as an attempt to flesh out this "process philosophy"[12] with increasingly concrete applications.

The Principia Cybernetica Project

While physics taught me how to use some very powerful mathematical and conceptual tools, its approach was too reductionist and deterministic to explain the complex, evolving nature of the phenomena that interested me most: life, mind and society. To better understand these, I soon turned to the theories of evolution, cognition, systems and cybernetics. An analysis of the role of the

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[7] I. Prigogine and I. Stengers, *Order Out of Chaos: Man's New Dialogue with Nature* (Bantam books, 1984); I. Prigogine, "From Being to Becoming. Time and Complexity in the Physical Sciences," *New York: Freeman, 1980* (1980).

[8] D. Aerts, "Quantum Structures: An Attempt to Explain the Origin of Their Appearance in Nature," *International Journal of Theoretical Physics* 34, no. 8 (1995): 1165–1186; D. Aerts, "Example of a Macroscopical Classical Situation That Violates Bell Inequalities," *Lettere Al Nuovo Cimento (1971–1985)* 34, no. 4 (1982): 107–111.

[9] Francis Heylighen, "Classical and Nonclassical Representations in Physics I," *Cybernetics and Systems* 21, no. 4 (1990): 423–444, http://www.tandfonline.com/doi/abs/10.1080/01969729008902251.

[10] Francis Heylighen, *Representation and Change: A Metarepresentational Framework for the Foundations of Physical and Cognitive Science* (Communication and Cognition, 1990).

[11] Francis Heylighen, "A Structural Language for the Foundations of Physics," *International Journal Of General Systems* 18, no. 2 (1990): 93–111.

[12] N. Rescher, *Process Philosophy: a Survey of Basic Issues* (Univ of Pittsburgh Pr, 2000).

observer in quantum theory together with the creation at our university by Luc Steels[13] of one of the first Artificial Intelligence labs in Europe inspired me to focus on cognition: the processes by which knowledge is acquired and represented. In 1986, I submitted a short paper looking at knowledge acquisition as relational self-organization to a conference on cybernetics. There I discovered a whole community of researchers interested in the same transdisciplinary subject of complex systems, their self-organization and cognition[14].

General systems theory and cybernetics in particular offered me a framework to analyse and model a great variety of systems, whether physical, chemical, biological, mental, or social. Its mathematical tools moreover were relatively close to the ones of physics, so that it cost me little effort to re-educate myself as a systems scientist/cybernetician. This reorientation seems to have been rather successful given that I have been invited to write several review articles about this domain for leading encyclopedias[15].

After defending my PhD thesis in 1987, I basically abandoned my work on the foundations of physics, and positioned myself squarely in the field of general systems and cybernetics, hoping that I had finally found my home. Yet, I felt there was still something lacking in that approach, which tended to consider systems as pre-existing, static structures, rather than as the result of a process of evolution. Therefore, the first thing that needed to be done was to inject evolution (and therefore a dynamics of distinctions) into that framework[16]. Within the cybernetics and systems community, I soon came into contact with two fellow thinkers, Cliff Joslyn and Valentin Turchin, who had similar intentions.

Turchin had started his career as a theoretical physicist in the Soviet Union, but was quick to grasp the importance of the new sciences of computing and cybernetics in the 1960's. He created the programming language REFAL for artificial intelligence, and laid the foundation for an evolutionary-cybernetic worldview[17]. His passion for free thinking and free speech, however, brought him in conflict with the Soviet authorities, so that he was forced to leave his country for the USA in 1977. Joslyn was a young American researcher deeply impressed by Turchin's theories, and fascinated by the new possibilities of the Internet to discuss, publicize and elaborate such a conceptual framework. Together, in 1990 we founded the Principia Cybernetica Project (PCP)[18], which aimed at developing evolutionary cybernetics as a foundation for an integrated evolutionary philosophy.

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[13] L. Steels and R. A Brooks, *The Artificial Life Route to Artificial Intelligence: Building Embodied, Situated Agents* (Lawrence Erlbaum, 1995); L. Steels, "The Origins of Ontologies and Communication Conventions in Multi-agent Systems," *Autonomous Agents and Multi-Agent Systems* 1, no. 2 (1998): 169–194.

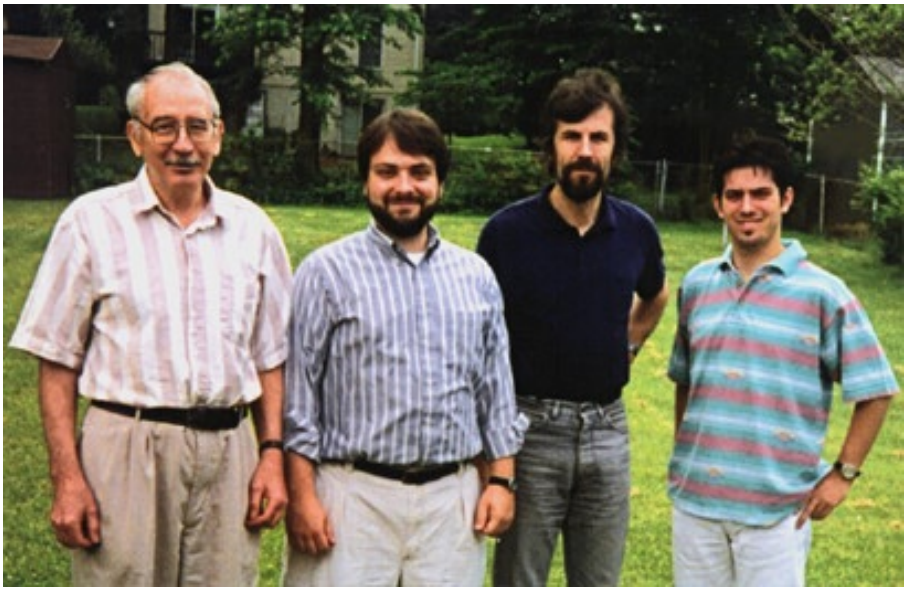
[14] Francis Heylighen, E. Rosseel, and Frank Demeyere, *Self-steering and Cognition in Complex Systems: Toward a New Cybernetics*, Studies in Cybernetics v. 22 (New York: Gordon and Breach Science Publishers, 1990).

[15] Francis Heylighen and C. Joslyn, "Cybernetics and Second Order Cybernetics," *Encyclopedia of Physical Science & Technology* 4 (2001): 155–170; Francis Heylighen and C. Joslyn, "Systems Theory," *Cambridge Dictionary of Philosophy*, 1996; Cliff Joslyn and Francis Heylighen, "Cybernetics," ed. D. Hemmendinger, A. Ralston & E. Reilly, *The Encyclopedia of Computer Science* (470-473: Nature Publishing Group, 2000).

[16] Heylighen, "Principles of Systems and Cybernetics."

[17] V. Turchin, "The Phenomenon of Science. A Cybernetic Approach to Human Evolution," *New York: Columbia University* (1977).

[18] F. Heylighen, C. Joslyn, and V. Turchin, "A Short Introduction to the Principia Cybernetica Project," *Journal of Ideas* 2, no. 1 (1991): 26–29; Francis Heylighen and C. Joslyn, "Electronic Networking for Philosophical Development in the Principia Cybernetica Project," *Informatica* 17, no. 3 (1993): 285–293; Francis Heylighen, "Foundations and Methodology for an Evolutionary World View: a Review of the Principia Cybernetica Project," *Foundations of Science* 5, no. 4 (2000): 457–490; Valentin Turchin, Cliff Joslyn, and Francis Heylighen, "Principia Cybernetica Web", 1993, http://pespmc1.vub.ac.be/.



The Principia Cybernetica Board in 1995: Valentin Turchin, Cliff Joslyn, myself, and my PhD student Johan Bollen

As initially conceived by Joslyn, PCP intended to use the Internet as a collaborative tool for developing a complex, encyclopedia-style knowledge network. This led me to explore the worldwide web from its very beginning in 1991[19], and to create the Principia Cybernetica Web[20] in 1993—as the first website in Belgium, and one of the first complex websites in the world[21]. The site quickly counted hundreds of pages written mostly by its editors (Turchin, Joslyn and myself) to introduce and review the major concepts surrounding the paradigm of evolutionary cybernetics. Measured by the number of downloads, reactions and citations, these pages proved very successful. From time to time, I still get reactions such as the following:

> "I enjoy reading principia cybernetica. Good that such a thing exists. Your writing has been very helpful in introducing me to various cybernetic concepts"

> "It has been a long time for me to know you from your outstandingly magnificent work of Principia Cybernetica."

It appears as though Principia Cybernetica Web has had a very broad and (I hope) deep impact, inspiring hundreds, if not thousands, of people to study the ideas of cybernetics and the related theories of evolution, systems and complexity.

The Center Leo Apostel

The transdisciplinary unification sought by PCP fitted in well with another initiative at my own university, the Center Leo Apostel (CLEA), an interdisciplinary research department founded under the inspiration of the philosopher Leo Apostel in order to develop integrative worldviews[22], and directed by my colleague Diederik Aerts. I joined CLEA in 1995, soon taking on the function of associate director. This finally provided me with a departmental "home", after detours across the

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[19] Tim Berners-Lee and Mark Fischetti, *Weaving the Web: The Original Design and Ultimate Destiny of the World Wide Web by Its Inventor* (Harper San Francisco, 1999), http://portal.acm.org/citation.cfm?id=554813; Francis Heylighen, "World-Wide Web: a Distributed Hypermedia Paradigm for Global Networking," in *SHARE EUROPE SPRING MEETING*, 1994, 355–368.

[20] Turchin, Joslyn, and Heylighen, "Principia Cybernetica Web."

[21] http://en.wikipedia.org/wiki/List_of_websites_founded_before_1995

[22] D. Aerts et al., "Worldviews: From Fragmentation to Integration," *Brussels: VUB Press, Online Access Http://www. Vub. Ac. be/CLEA/pub/books/worldviews. Html* 12 (2002).

departments of physics, psychology and philosophy. But quite a number of steps had to be taken before I could truly join such an interdisciplinary center.

In 1984, as a young researcher in the Theoretical Physics department, I had come into contact with the psychologist Prof. De Waele and his then assistant Luc Van Langenhove. As we shared the ideal of promoting interdisciplinary research at the VUB, we founded the informal "Transdisciplinary Research Group". Its primary activity was the organization of seminars and discussions around an enjoyable dinner. The group involved several of the most open-minded researchers from the VUB and Ghent University, including Erik Rosseel, Paula Burghgraeve, my thesis advisor Jean-Paul Van Bendegem, and my former mentor Diederik Aerts.

By 1987, our ambitions had expanded to the international level. This resulted in the organization of a well-attended 3-day conference on "Self-steering and cognition in complex systems"[23], and a summer school on "Self-organization of cognitive systems". The time seemed ripe to formalize the informal group, so in 1989 I wrote a proposal for the creation of an interdisciplinary research center, which we presented to the VUB authorities. It included an outline of the research philosophy, which centered on the three themes of evolution, systems, and cognition that would also form the core of Principia Cybernetica.

However, at the same time, the late philosopher Leo Apostel had independently submitted a similar proposal for a transdisciplinary research group focused on the construction of integrating worldviews. Given Apostel's fame, the VUB decided to honor only the latter proposal, so as not to divide resources over two transdisciplinary research groups. Out of this proposal was created the Center Leo Apostel (CLEA), mainly as a meeting place for senior professors from different departments, where they could discuss the similarities and differences between their disciplinary approaches.

However, after a few years, the activities of this Center dwindled because these department heads had a busy agenda and little energy to invest in interdisciplinary research. Apostel himself noted that the Center was not achieving its objectives, and therefore decided to start with a clean slate. In 1995, CLEA was drastically reorganized under the leadership of Diederik Aerts, now taking in mostly younger researchers, including myself and other members of the former Transdisciplinary Research Group, in order to work on concrete projects. This approach proved much more successful: the Center acquired the funding that allowed it to employ several PhD students, while quickly producing an impressive list of international publications and collaborations.

The Global Brain

PCP was not as successful as expected in its aim of getting people worldwide to collaborate on its conceptual network[24]. In practice, apart from the editors, just a few people contributed good material to the site. In hindsight, it seems that we lacked the user-friendly wiki technology that later made Wikipedia into such a worldwide success. We also underestimated the difficulty of organizing the knowledge in the form of a coherent semantic network—a difficulty similar to the one that is still holding back the spread of the "semantic web"[25].

On the other hand, the associative nature of the web inspired me to look for a self-organizing solution to the problem of the organization of knowledge. Together with my then PhD student Johan Bollen, I developed and tested a series of algorithms that would allow a website to "learn" the implicit associations that its users make between different pages, and that would use the learned structure in the way of a neural network to suggest relevant pages via the mechanism of spreading

[23] Heylighen, Rosseel, and Demeyere, *Self-steering and Cognition in Complex Systems*.
[24] Heylighen, "Foundations and Methodology for an Evolutionary World View: a Review of the Principia Cybernetica Project."
[25] Berners-Lee and Fischetti, *Weaving the Web*; Francis Heylighen, "Conceptions of a Global Brain: An Historical Review," in *Evolution: Cosmic, Biological, and Social, Eds. Grinin, L. E., Carneiro, R. L., Korotayev A. V., Spier F.* (Uchitel Publishing, 2011), 274 – 289, http://pcp.vub.ac.be/papers/GB-conceptions-Rodrigue.pdf.

activation[26]. When viewed from the broader PCP perspective, this similarity between web and neural network suggested the concept of a Global Brain to me, i.e. a distributed intelligence emerging from the Internet[27]. Together with Ben Goertzel, an AI-researcher who had come to a similar understanding, in 1996 I founded the Global Brain Group, an international discussion forum that grouped most of the researchers who had written on this subject. This also stimulated my interest in the phenomenon of collective intelligence, about which I published a highly cited paper[28] in which I generalized my "learning web" algorithms.

One handicap of both PCP and the (overlapping) Global Brain group was that our aims were much more specialized than those of the similarly organized Wikipedia, demanding a high level of expert knowledge and insight into collective intelligence and evolutionary cybernetic thinking. This strongly limited the number of people capable of making high-quality contributions.

On the other hand, there was no lack of people motivated to acquire such knowledge. As soon as I mentioned the possibility to do PhD research within the Principia Cybernetica domain, we started getting applications from students across the world willing to work towards such a degree. Since I was the only one of the editors in a practical position to supervise such study, most of these applicants ended up with me at the VUB. From about the year 2000, the activities of PCP gradually dwindled, as its senior founder, Valentin Turchin became ill and eventually died, and the other editors became increasingly busy at their own institutes. The same happened to a smaller extent with the Global Brain group.

The ECCO paradigm

This led me to refocus my attention to the growing group of PhD students and other researchers that had come to work with me in CLEA at the VUB. Eventually, in 2004, I decided to assemble them in a new research group within the CLEA framework, which we called ECCO, an abbreviation for the "Evolution, Complexity and COgnition group".

Given that most ECCO members had come to me via PCP, the philosophy of ECCO was an extension of the Principia Cybernetica approach: a transdisciplinary investigation of the evolution of complex and, in particular, intelligent organization. However, with a new generation, there was a shift in focus, which corresponded roughly to the shift from the older theory of cybernetics to the newer paradigm of *complex adaptive systems*[29] or, more generally, complexity science. Conceptually, the main difference was that complex adaptive systems have a much looser, more variable organization than typical cybernetic systems, as they consist of changing coalitions of agents that are partly competing, partly cooperating, and partly ignoring each other.

This more anarchic structure, paradoxically, allowed me to overcome a major theoretical obstacle that had hampered PCP: how do metasystem transitions occur? Valentin Turchin had defined a metasystem transition as the evolutionary emergence of a new level of control or

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[26] Johan Bollen and Francis Heylighen, "Algorithms for the Self-organization of Distributed, Multi-user Networks. Possible Application to the Future World Wide Web," *CYBERNETICS AND SYSTEMS RESEARCH* (1996): 911–916; Johan Bollen and Francis Heylighen, "A System to Restructure Hypertext Networks into Valid User Models," *New Review of Hypermedia and Multimedia* 4, no. 1 (1998): 189–214; Francis Heylighen and Johan Bollen, "Hebbian Algorithms for a Digital Library Recommendation System," in *International Conference on Parallel Processing* (Los Alamitos, CA, USA: IEEE Computer Society, 2002), 439, http://pespmc1.vub.ac.be/Papers/Digital_libraries.pdf.

[27] Heylighen, "Conceptions of a Global Brain"; Francis Heylighen, "The Global Superorganism: An Evolutionary-cybernetic Model of the Emerging Network Society," *Social Evolution & History* 6, no. 1 (2007): 58–119; Francis Heylighen and Johan Bollen, "The World-Wide Web as a Super-Brain: From Metaphor to Model," in *Cybernetics and Systems' 96. R. Trappl (Ed.). Austrian Society For Cybernetics*, 1996.

[28] Francis Heylighen, "Collective Intelligence and Its Implementation on the Web: Algorithms to Develop a Collective Mental Map," *Computational & Mathematical Organization Theory* 5, no. 3 (1999): 253–280, http://pcp.vub.ac.be/papers/CollectiveWebIntelligence.pdf.

[29] J. H Miller, S. E Page, and B. LeBaron, *Complex Adaptive Systems: An Introduction to Computational Models of Social Life* (Princeton University Press Princeton and Oxford, 2007); J. H. Holland, *Hidden Order: How Adaptation Builds Complexity* (Addison Wesley Publishing Company, 1996).

organization, a fundamental process typified by such revolutionary events like the origin of life, the origin of multicellular organisms, and the emergence of human culture[30]. Within his cybernetic framework, he could elegantly describe the situation before and after the transition, but the details of the transition itself remained vague. Together with my PCP colleagues and others, I had made several attempts to clarify the dynamics of this process[31], but I remained dissatisfied with my understanding of the phenomenon.

The perspective of complex adaptive systems led me to reconceptualize the process as the self-organization of a group of interacting agents[32]. Such self-organization is an extended, continuous process, which may be characterized by various false starts, detours, and throwbacks, and which is never really finished. This seems to offer a much more realistic model of what we know about the transitions that have taken place throughout evolutionary history. On the other hand, this agent-based conceptualization did confirm the general idea of evolutionary progress, in the sense of a continuing growth of complexity, adaptivity and intelligence[33], which was at the basis of the Principia Cybernetica philosophy.

Reasoning in terms of interacting agents clarified several other fundamental issues for me. Turchin had started to develop an ontology of action[34] that in some respects echoed my earlier process ontology[35], but that remained equally abstract, as both were inspired by theoretical physics. Reinterpreting both perspectives in terms of agents interacting with their environment and each other made everything much more concrete: the ontology of action could now be directly applied to the modeling and simulation of biological, cognitive, social and economic systems, as the complex adaptive systems approach[36] already demonstrated, although it still lacked theoretical foundations. While discussing these issues with my colleagues in ECCO, who had been working on the same kind of problems, more and more of the pieces of the puzzle started to fall into place. The provisional result of this exercise at synthesis led me to formulate an extensive review of the "ECCO paradigm" for transdisciplinary unification: an action-based conceptual framework that may help us to understand, model and design any kind of complex, evolving system[37].

Challenge Propagation

This conceptual framework considers two aspects of action: individual and collective. On the individual level, I recently introduced the concept of *challenge*, as a situation that incites an agent to

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[30] Turchin, "The Phenomenon of Science. A Cybernetic Approach to Human Evolution"; V. Turchin, "A Dialogue on Metasystem Transition," *World Futures* 45 (1995): 5–57.

[31] Francis Heylighen, "Cognitive Levels of Evolution: From Pre-rational to Meta-rational," *The Cybernetics of Complex Systems-Self-organization, Evolution and Social Change* (1991): 75–91; Francis Heylighen and C. Joslyn, "Towards a Theory of Metasystem Transitions: Introduction to the Special Issue" (1995); Francis Heylighen and Donald T. Campbell, "Selection of Organization at the Social Level: Obstacles and Facilitators of Metasystem Transitions," *World Futures* 45, no. 1–4 (1995): 181–212; Francis Heylighen, "(Meta)systems as Constraints on Variation— a Classification and Natural History of Metasystem Transitions," *World Futures* 45, no. 1 (1995): 59–85; Francis Heylighen, "Evolutionary Transitions: How Do Levels of Complexity Emerge?," *COMPLEXITY* 6, no. 1 (2000): 53–57.

[32] Francis Heylighen and C. Gershenson, "The Meaning of Self-organization in Computing," *IEEE Intelligent Systems, Section Trends & Controversies-Self-organization and Information Systems* (2003); Francis Heylighen, "Complexity and Self-organization," *Encyclopedia of Library and Information Sciences, Eds. MJ Bates & MN Maack Taylor & Francis* (2008); Francis Heylighen, "Self-organization in Communicating Groups: The Emergence of Coordination, Shared References and Collective Intelligence," in *Complexity Perspectives on Language, Communication, and Society*, ed. Angels Massip-Bonet and Albert Bastardas-Boada, Understanding Complex Systems (Springer, 2013), 117–150, http://pcp.vub.ac.be/Papers/Barcelona-LanguageSO.pdf.

[33] Francis Heylighen, "The Growth of Structural and Functional Complexity During Evolution," in *The Evolution of Complexity*, 1999, 17–44; Francis Heylighen and J. Bernheim, "Global Progress II: Evolutionary Mechanisms and Their Side-effects," *Journal of Happiness Studies* 1, no. 3 (2000): 351–374.

[34] V. F. Turchin, "The Cybernetic Ontology of Action," *Kybernetes* 22 (1993): 10–10.

[35] Heylighen, "A Structural Language for the Foundations of Physics."

[36] Miller, Page, and LeBaron, *Complex Adaptive Systems*.

[37] Francis Heylighen, "Self-organization of Complex, Intelligent Systems: An Action Ontology for Transdisciplinary Integration," *Integral Review* (2011), http://pespmc1.vub.ac.be/Papers/ECCO-paradigm.pdf.

act. This allowed me to connect the scientific perspective on behavior with the narrative perspective that is found in myths and stories, and which depicts an individual's course of action as an *adventure*, i.e. a sequence of typically unforeseen challenges that the individual has to tackle. Although this work has not been published yet (I plan to submit the paper[38] to the high-impact journal *Behavioral and Brain Sciences*), I consider it as a great step forward in the development of a truly integrated worldview, offering a synthesis of mythical-literary and scientific perspectives.

On the collective level, the concept of challenge offers a tool to better model the dynamics of self-organization that characterizes the emergence of cooperation and collective intelligence in a group of interacting agents. The only thing that needs to be added to the individual analysis is a mechanism of *propagation*: an agent acting on a challenge typically creates a new challenge for one or more other agents. When these agents act in turn, they create further challenges, thus propagating the initial challenge across a widening neighborhood. This sets in motion a train of activity that only comes to a halt when the challenge has been satisfactorily "relaxed", a situation that can be interpreted as a solution to the collective problem defined by the challenge.

The new concept of challenge propagation can be seen as a generalization of the mechanism of spreading activation that I had used to conceptualize the distributed intelligence of the Global Brain. In 2011, I was contacted by the Russian Internet investor Yuri Milner who had independently arrived at the notion of a Global Brain, and then made a survey of the research done on this phenomenon. He concluded that I seemed to be the most expert in this domain, and therefore offered me a substantial amount of funding to investigate the Global Brain in more depth. With this money, in January 2012 I founded the Global Brain Institute (GBI) at the VUB, employing five full-time researchers, mostly selected from the existing ECCO group, while inviting several of my old colleagues from PCP, the Global Brain group, and ECCO to sit on the institute's scientific board. Given the sponsor's background in theoretical physics, we agreed that our initial target would be the development of a theory and mathematical model of the Global Brain, complemented by a survey of various applications of the web to support collective intelligence. If these targets are met, the sponsor promised to significantly increase the GBI funding. Given that the challenge propagation paradigm seems ready to be elaborated into a detailed mathematical model[39] and that the researchers I selected all are highly qualified and motivated to work on this subject, I have good hope that the GBI will quickly grow into an internationally recognized center of excellence.

Happiness and self-actualization

My fascination for spontaneous, "free" processes, which led me to investigate the self-organization of groups of agents, also directed my interest in individual behavior. I had always had the impression that most people did not behave naturally or spontaneously (which is one of the reasons I preferred to be busy with minerals, plants and animals). To me, they appeared perpetually restrained by rules, traditions and expectations, and the fear of doing something that others might consider wrong. Initially, I couldn't quite understand why there seemed to be such a difference between this rigid, repressed attitude and the playfulness, self-confidence, and sense of adventure that I had personally experienced from childhood on. I did learn quickly that I was not supposed to behave too spontaneously in the presence of such people, and therefore I tended to be rather shy and withdrawn in public, preferring to be alone or with a few close friends or family members, to whom I could show my real self.

This feeling of being different from the others was one of the reasons why I became interested in psychology. After reading some of the classic theories about intelligence, personality

[38] Francis Heylighen, *A Tale of Challenge, Adventure and Mystery: Towards an Agent-based Unification of Narrative and Scientific Models of Behavior*, ECCO Working Papers, 2012.

[39] Francis Heylighen, *Challenge Propagation: a New Paradigm for Modeling Distributed Intelligence*, GBI Working Papers, 2012; Francis Heylighen, *The GBI Vision: Past, Present and Future Context of Global Brain Research*, GBI Working Papers, 2011.

and motivation, I stumbled upon Abraham Maslow's book[40] in which he describes the self-actualizing personality. This was a profound revelation, as the "self-actualizing" behavior and attitudes described by Maslow perfectly fitted my own. Moreover, Maslow proposed self-actualization as a model of optimal psychological health and well-being, making the concept even more attractive for someone interested in general progress. However, I found Maslow's explanation for self-actualization, based on his hierarchy of needs, to be rather vague. Therefore, I set out to review and "reconstruct" his theory using the more advanced concepts I had learned in cybernetics and cognitive science. The resulting paper[41], written around 1989, seems to have made a certain impact, and still gets regularly cited. Yet, I had the feeling that there was still much I did not quite understand about individual well-being.

Under the impulse of my friend and colleague, Jan Bernheim, who had been developing the ACSA method for measuring quality-of-life, I turned to the study of happiness. As a result, I eventually became an editorial board member of the presently quite successful "Journal of Happiness Studies", which was then edited by Ruut Veenhoven. Veenhoven's sociological studies[42] of the conditions for happiness inspired Jan and me to examine how these conditions had changed over time. Our conclusion was that the world was undeniably progressing on most fronts[43], although the stresses caused by accelerating change and information overload cast some worrying shadows[44] on this optimistic, progressive worldview. The problem remained for me to explain why in such relatively good circumstances self-actualization remained such a rare phenomenon.

A book by the evolutionary anthropologist Chisholm[45] gave me an important clue, which I further developed in a paper with Jan[46]. The idea is that natural selection can either go for quality (long life, few offspring, extended development) or for quantity (many offspring, short life, limited development), depending on the level of predictability in the environment: in risky environments, where organisms have little control over their survival, the best strategy is to have a lot of offspring as quickly as possibly without thinking about later (r-selection); in stable environments, it pays to invest a lot in the long-term development of a few offspring (K-selection). Chisholm gathered a lot of evidence to show that the same pattern appears in human development: children raised in a stressful environment develop a short-term, anxious outlook on life. Self-actualization and happiness, in my interpretation, on the other hand, are the products of a stable, relaxed, caring childhood environment.

The problem remained to explain why our present, wealthy and safe society still produces so many anxious, neurotic people. I found a solution via the detour of my on-going quest for the healthy diet and lifestyle that would maximize my quality-of-life now and in old age.

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[40] Abraham H. Maslow, *Motivation and Personality*, 2nd ed. (New York: Harper & Row, 1970).

[41] Francis Heylighen, "A Cognitive-systemic Reconstruction of Maslow's Theory of Self-actualization," *Behavioral Science* 37, no. 1 (1992): 39–58.

[42] R. Veenhoven, "Advances in Understanding Happiness," *Revue Québécoise De Psychologie* 18, no. 2 (1997): 29–74.

[43] Francis Heylighen and Jan Bernheim, "Global Progress I: Empirical Evidence for Ongoing Increase in Quality-of-life," *Journal of Happiness Studies* 1, no. 3 (2000): 323–349.

[44] Heylighen and Bernheim, "Global Progress II: Evolutionary Mechanisms and Their Side-effects."

[45] James S. Chisholm, *Death, Hope and Sex: Steps to an Evolutionary Ecology of Mind and Morality*, 1st ed. (Cambridge University Press, 1999).

[46] Francis Heylighen and J. Bernheim, *From Quantity to Quality of Life: rK Selection and Human Development* (ECCO working paper 2004-02, 2004).

Erwan Le Corre (right), illustrating some Paleo principles during a MovNat workshop

The Paleo lifestyle

In 2009, I ran into Loren Cordain's website on the "Paleolithic diet"[47], i.e. the diet based on the foods that our hunter-gatherers ancestors were adapted to eat. As an evolutionary theorist, it made perfect sense to me that this diet would indeed be healthier than the industrially processed foods most of us are eating now, so I immediately started exploring this approach and its ramifications. The same logic applied to other elements of the "Paleolithic lifestyle": our body and mind have adapted over millions of years to the life of hunter-gatherers, foraging for plants and animals in small bands across the wide-open, natural landscape. The discovery of a small, but growing "Paleo" community of people exploring and trying to apply these ideas to their own life was another revelation for me. On my invitation, one of the founding fathers of that community, the complexity theorist Arthur De Vany[48], soon after joined the ECCO group.

My deep and instinctive love of nature, adventure and exploration now made perfect sense to me: that is what natural selection had programmed my genes to long for and thrive on! The full emotional impact of this idea came when I saw the breathtakingly beautiful videos of Erwan Le Corre, demonstrating his "MovNat" philosophy of natural movement in natural surroundings. Inspired by the work of Le Corre, Cordain, De Vany and others, I created my own website and started writing an (as yet unfinished) paper on the implication of the paleo paradigm for well-being. To me it was intuitively clear that the freedom and spontaneity of the "natural lifestyle" promoted by Le Corre and De Vany was similar in spirit to what Maslow called "self-actualizing behavior".

This finally gave me a good explanation for the rarity of self-actualization in modern society. The agricultural and industrial eras that followed the Paleolithic were by definition "unnatural": they

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[47] Loren Cordain, *The Paleo Diet: Lose Weight and Get Healthy by Eating the Food You Were Designed to Eat* (Wiley, 2002); Melvin Konner and S. Boyd Eaton, "Paleolithic Nutrition," *Nutrition in Clinical Practice* 25, no. 6 (December 1, 2010): 594 –602, http://ncp.sagepub.com/content/25/6/594.abstract.

[48] Arthur De Vany, *The New Evolution Diet: What Our Paleolithic Ancestors Can Teach Us About Weight Loss, Fitness, and Aging* (Rodale Books, 2010).

not only tried to control the natural world, but also our natural instincts for interacting with that world. The reason is that agricultural and industrial workers need to follow a strict, rule-governed discipline that goes counter to the more relaxed, impulsive lifestyle of a hunter-gatherer. Therefore, society has developed a variety of explicit and implicit methods for suppressing spontaneous behavior, as exemplified by different procedures used in the army, school, church and law. This effect is enhanced by the fact that the unnaturalness of modern life is intrinsically stressful to our body and mind[49], producing an r-style environment that promotes anxiety and inhibits happiness and self-actualization. The good news is that thanks to technological advances, we no longer need to follow rigid rules, and should be able to reintroduce the most important elements of Paleolithic life in our present lifestyle.

[49] B. Grinde, "Happiness in the Perspective of Evolutionary Psychology," *Journal of Happiness Studies* 3, no. 4 (2002): 331–354; S. E Hill and D. M Buss, "Evolution and Subjective Well-being," *The Science of Subjective Well-being* (2008): 62–79.